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1862

CASES OF RIGHT AORTIC ARCH

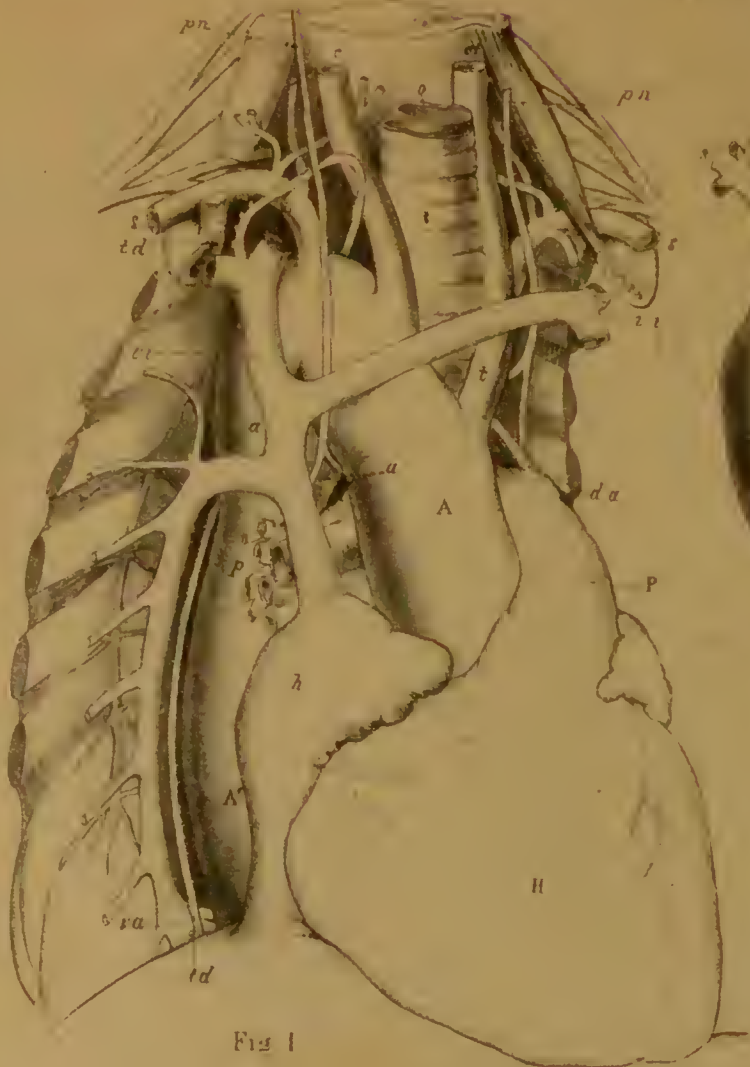

Fig 1

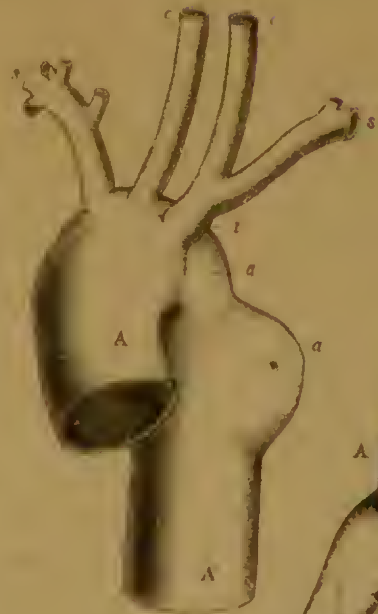

Fig 3

Fig 2

DESCRIPTION OF THE DISSECTION

OF A

CASE OF RIGHT AORTIC ARCH;

WITH

REMARKS ON THIS AND ALLIED MALFORMATIONS.

BY

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THE case of malformation which forms the subject of the following communication belongs to a series which has attracted considerable attention from anatomists, in consequence of their close relation to the embryological changes which occur in the course of the development of the permanent arterial vessels connected with the heart; and I am induced to publish a detailed account of it, because it appears to me to be somewhat different from any other cases belonging to the same group with which I am acquainted as having been described, and more particularly because it seems to supply a link that was wanting, to complete the graduated series of abnormal conditions of the vessels which has been found to bear an intimate relation to the remarkable transitory conditions presented by the arterial system of the upper part of the body, in the earliest period of fœtal life. It constitutes what may shortly be termed a simple case of Right Aortic Arch; or in other words, it is an instance of the arch of the aorta being placed to the right side of the trachea and gullet, instead of as usual to the left, without transposition of the heart or other viscera; but accompanied by a reversal of the order in which the right and left brachio-cephalic vessels arise from the arch, and some other abnormal dispositions of the parts.

As these abnormal conditions can only be rightly understood by referring them to the embryological structure, and as some very interesting relations are brought into view by this reference,

I may be excused if, before describing the dissection of the case at present under consideration, I premise, for the sake of those who are not familiar with embryology, a short account of the early conditions of the aortic vessels in man and animals, and of the more important changes by which the permanent disposition of these vessels is brought about.

In this sketch I omit for the present the consideration of the earliest condition of the aorta, in which it is double throughout its whole extent, and start from a period when, by the coalescence of its two primitive roots, the main trunk, or descending aorta, forms a single and median vessel—a period which corresponds nearly to the state of advancement of the human embryo between the third and fourth week after conception, and to that of the chick at the middle of the third day of incubation.

At this period in the human embryo, as in that of all vertebrate animals, there have been formed in the region corresponding to the space between the head and breast, and in which the neck is afterwards formed, a series of vascular arches in pairs, to the number of five. The vascular arches all spring in front from the common primitive arterial stem, sometimes called the aortic bulb, which is at first the only arterial outlet from the ventricular part of the heart; and passing round the wall of the body, unite behind or towards the dorsal region* into a single vessel on each side, which may be named the right and left roots of the descending aorta, seeing that the two vessels so formed come together in the middle line in front of the dorsal vertebræ to constitute the thoracic aorta.

The aortic bulb or primitive arterial stem, from which the pairs of vascular arches spring, is situated in front of the pharyngeal portion of the alimentary canal, and the aortic roots and descending aorta are behind it; so that the four first arches pass over the side of the pharynx in the substance of those fœtal structures, which have been named the branchial or visceral plates, while the fifth arch is similarly placed below the fourth plate; and thus the four branchial clefts or apertures, which pass through the lateral walls of the pharynx from the external surface, are placed on either side, one below each branchial plate and between two vascular arches.†

In all the different classes of vertebrate animals the permanent arteries of the upper part of the body, and the pulmonary arteries where they exist, owe their origin to farther changes undergone

* It may be proper to state here that the terms before and behind, above and below, are employed in this paper in the sense which is applicable to human anatomy.

† According to most embryologists the Batrachia have only four arches; but this may be doubtful, as Remak has represented in Tab. x., fig. 21 of his "History of the Development of the Chick and Frog," five pairs of arches, as given off from the primitive arterial stem.

by the vascular framework now described. In the aquatic tribes the vessels of the gills are produced by transformation of all the five, or of four, or of three only, of the vascular arches in connection with the other parts of the branchial organs, which it does not come within the scope of the present paper to describe.*

In the adult batrachia the aortic bulb remains as the sole exit from the ventricular cavity, and the double arch of the aorta is formed by the persistence of two entire arches, which pass one on each side round the pharynx to unite in the single dorsal aorta. Two other pairs of arches remain open on each side in the first part of their course to form the stems, the one pair of the carotid, and the other of the pulmonary arteries; while their communications with the aortic roots have been obliterated.

In the remaining classes of vertebrate animals, the following are the principal changes which have been ascertained to attend the formation of the permanent vessels, by the observations of a variety of embryologists, but in particular by the interesting researches of Von Baer and Rathke.†

In serpents, lizards, and turtles, the fourth pair of primitive vascular arches remain persistent in their whole extent, and are continued into the aortic roots so as to constitute the right and left aortic arches of the adult condition. The fifth arches remain open during a part or the whole of fœtal life as ductus arteriosi, leading into the aortic roots on each side; and the pulmonary arteries are developed from one or both of the anterior parts of the fifth arches. The carotid arteries are formed in connection with the first, second, and third arches, being left in communication with the right permanent aortic arch; the exact mode of origin of the subclavian arteries in Chelonia does not appear to be known, but in Sauria they spring from the lower part of the aortic roots. In all the scaly reptiles the canal of the aortic bulb undergoes a division into three vessels, of which one is in communication with the right or true systemic aorta, and leads from the posterior or left division of the ventricular cavity; the second tube is continued into the left root of the aorta, and the third into the pulmonary trunk; both of these last tubes being in communication with the right or anterior division of the ventricular cavity.

In birds one entire arch, the fourth on the right side, remains in the adult, as the permanent aorta, which passes over the right

* The more numerous arches of the Cyclostomatous fishes, which are also all converted into branchial vessels, have, in the above, been left out of consideration.

† I refer here to the second part of Von Baer's work on Development, published in 1839 (see note at p. 212), and to the paper of Rathke in Müller's Archiv for 1843, p. 276. The most recent researches of Rathke are contained in a memoir, published in the Transactions of the Imperial Academy of Vienna for the year 1859, and form the basis of the more accurate knowledge of this subject at the present day, and of the sketch now given.

side of the trachea and gullet, and is brought into communication with the left ventricle by one of the two canals into which the aortic bulb divides. The pulmonary arteries are probably formed by the extension of vessels from the middle part of both the fifth arches, and are brought into communication with the right ventricle by the second tube of the arterial bulb; and during fœtal life the whole of the fifth right arch, as well as that of the left side, with the left aortic root, remain patent to form the two ductus arteriosi of this class of animals. The two brachio-cephalic arteries of birds result from the persistence of portions of the fourth arches communicating with the third, from which the carotid arteries are continued, and with subclavian arteries developed outwards from the back part of the aortic roots beyond the fourth arch.

In mammalia there are also five pairs of vascular arches, of which in the fœtus at one period three and sometimes four may be observed together. The changes in the first three, connected with the formation of the carotid arteries, are nearly the same as those previously referred to in the lower vertebrata; but in the fourth and fifth they are somewhat different, in so far as the permanent aorta proceeds from the fourth arch on the left side, and according to Rathke's most recent researches, it is only one of the fifth arches, viz., the left, which gives the common trunk of the right and left pulmonary arteries; and from this one necessarily proceeds the single ductus Botalli of the left side. The whole of the fifth right arch thus disappears at an early period. Both fourth arches give off the vertebral arteries at their posterior part, and near the place where the aortic roots are joined by the fifth arch, but farther down on the right than on the left side, they give off the vessels which become the subclavian arteries, with which at a later period the vertebral arteries come to coalesce in the same stem. The anterior part of the fourth arch on the right side forms the innominate or right brachio-cephalic artery, which, as it remains proportionately smaller, seems now like a branch of the fourth left arch; while the left carotid and left subclavian trunks remain as separate vessels rising from the same arch, which forms the permanent aorta.

This is what occurs in man, and in some other mammalia presenting the same arrangement of these vessels; but in others in which the arrangement is different, there must be some modifications of the plan of development now described. Into these differences, however, it is unnecessary to enter more particularly at present. I will only remark, with regard to the natural origin of the brachial and cephalic vessels from the arch of the aorta, that in those animals, as in birds, in which the permanent aorta passes to the right of the trachea and gullet, or is a right arch, the left brachio-cephalic vessels always spring first from the

arch; whereas in mammalia possessing naturally the permanent arch on the left side, and having distinct brachial and cephalic vessels rising from its summit, those of the right side are the first to leave the main stem.

It is farther to be noted that the pneumogastric nerve, as it passes from above downwards, from without the vascular arches, to join the root of the lungs and the gullet on each side, gives off its recurrent or inferior laryngeal branch below the last arch; and as the latter nerve proceeds upwards to the larynx within the vascular arches, it follows that when the neck comes to be elongated by the extension of the parts between the third and fourth vascular arches, the pneumogastric nerve is drawn down with the lowest persistent arch, round which the recurrent laryngeal nerve is bent. If then any of the lower arches should permanently disappear, we may expect to find the bend of the recurrent nerve not passing lower than the place where it is held down by the next persistent arch. To this circumstance is attributable the difference in the position

DIAGRAM OF THE TRANSFORMATIONS OF THE AORTIC ARCHES.

A P, Primitive arterial stem, or aortic bulb, divided into, A, ascending aorta, and, P, pulmonary trunk; *d*, ductus arteriosus from the fifth left arch.

a, Right, *a'*, left aortic root.

A', Descending aorta.

1, 2, 3, 4, and 5, The aortic, branchial or visceral arches, marked on the right side; on the left side, the four branchial or pharyngeal clefts are seen between the arches.

It may be observed that, while the fourth and fifth arches come off directly from the primitive aortic trunk, the first, second, and third arches are branches of a secondary stem on each side.

c, Permanent common carotid arteries, still short before the elongation of the neck.

cc, External carotid arteries.

ci, Right, and *ci'*, left internal carotid arteries.

r, Right, *r'*, left vertebral arteries.

s, Right, *s'*, left subclavian arteries.

pn, Right, *pn'*, left pneumogastric nerves, represented (theoretically) as giving their recurrent laryngeal branches round and within the fifth arches.

and relations of the nerve on the right and left sides in man and the higher animals.

It is extremely difficult, if not impossible, in a few words to give any precise statement, or to convey a clear idea of the nature of the genetic processes by which the form and position of the vessels above referred to are ultimately determined. I can do no more in this place than merely mention them as consisting mainly in the occurrence of various degrees of patency or occlusion of entire arches or of parts of them, and in proportional increase of growth or atrophy of those parts which may have remained open or been closed. But to these must be added another set of changes, consisting in the lengthening or shortening of parts of the arches or stems of the vessels, which may have the effect not merely of altering the relative distances at which these vessels arise from the main stem, but even of collecting into one trunk, or of separating more widely from each other, any two or more of the vessels proceeding from one or more stems or arches.

In conformity with the preceding statement of the general plan of development of these vessels, and in explanation of the accompanying woodcut, which is designed to assist the comprehension of the reader by presenting a diagrammatic sketch of the aortic vascular transformation in man, the following table of the parts of the upper arterial system engaged in these transformations may be of use:—

I.—PRIMITIVE FŒTAL PARTS.

1. Primitive Arterial Stem or Aortic Bulb, afterwards divided by a septum into systemic or aortic and pulmonary canals.
2. Five Pairs of Arterial Vascular Arches (the branchial or visceral arches) proceeding from the primitive stem, or from its two primary branches, and forming by their union,
3. The Right and Left Dorsal Roots of the Aorta, which, having been at first separate, are at a very early period united in
4. The Descending Aorta.

II.—SECONDARY PARTS.

5. Entire Persistent Arch or Arches, proceeding from those which remain entirely patent and augment proportionally in growth.
6. Partially Persistent Arches, either
   a. Anteriorly, giving origin to the stems of the brachial and cephalic and of the pulmonary arteries, or
   b. Posteriorly, giving rise to a part of the internal carotid arteries.
7. Ductus Arteriosi, produced by temporary persistence of one or both the fifth arterial arches in connection with the permanent aortic root or roots.

The various cases of abnormal form and position of the great arterial vessels connected with the heart, may be best arranged and understood by referring them to deviations from the normal

modes of development previously sketched; and they may thus be found to fall suitably under the six following groups:—

1. Abnormal situation of the aorta, pulmonary artery, and their largest branches in connection with lateral inversion of the heart and great vessels, with or without the inversion of other viscera.
2. Abnormal modes of communication of the aorta and pulmonary artery with the ventricles.
3. Abnormal form and position of the principal or fourth and fifth primitive arches, under the following subdivisions:—
   a. Double aortic arch.
   b. Right aortic arch.
   c. Pulmonary arch (ductus arteriosus) continued into the descending aorta or other systemic vessels.
      c.* With aortic arch patent.
      c.** With back part of aortic arch closed.
4. Abnormal modes of origin of the large arteries from the summit of the aortic arch.
5. Abnormal conditions of the posterior aortic roots.
6. Abnormal conditions of the descending aorta.

The very numerous cases which have been recorded of such malformations are not, however, always quite simple in their nature, but frequently present various combinations of the abnormal conditions belonging to more than one of the groups above distinguished, more particularly among those belonging to the third, fourth, and fifth groups. Of this the case which forms the subject of the present paper, coming under the third group (subdivision *b*), will give an example.

It is not my intention in the present paper to discuss the subject of malformations of the aorta in general. For the best account of these malformations the reader is referred to the masterly works of Tiedemann, "Tabulæ Arteriarum," &c., and Richard Quain, "Commentaries on the Arteries," and to the recently published able essay "On the Irregularities of the Large Bloodvessels" in the British and Foreign Medico-Chirurgical Review for July and October, 1862, by Mr. William Turner, Demonstrator of Anatomy in the University of Edinburgh. In this essay Mr. Turner has carefully collected and reviewed the different cases recorded by previous writers, and has pointed out the relation of a large number of them to the fœtal condition, besides adding some observations of his own.

The arrangement I have given above, and which I have for many years adopted in my lectures, differs somewhat from the one proposed by Mr. Turner, which does not appear to me to recognize sufficiently the distinction between simple cases of right aorta and those which are associated with lateral inversion or transposition of the heart.

The malformation now to be described occurred in the body of

an adult male of middle stature, which was examined in the dissecting-room of the university in the year 1857. The disease of which the person died had no connection with the aorta, nor was the existence of the malformation known previous to his decease.

The two drawings, in Figs. 1 and 2 of the Plate, represent the right and left sides of the heart and aorta, with some of the adjacent parts, and will enable the reader to form a sufficiently clear idea of the general features of the malformation. I subjoin the following account of the preparation. The aorta at its origin from the left ventricle of the heart is placed in its normal relation to the pulmonary artery and other parts, and is not, therefore, as in cases of lateral transposition, situated to the left of the pulmonary artery. Its ascending part or sinus is somewhat more dilated than usual, and passes upwards and to the right side of the trachea and gullet into the curve of the arch, which rises as high as the body of the second dorsal vertebra. Here the arch is placed on the right side of the bodies of the vertebræ, and from thence it passes by a sudden bend into the descending part of the thoracic aorta. The latter part of the vessel is not straight as usual, but presents a long curve, with its convexity directed towards the right side in the region of the eighth, ninth, and tenth dorsal vertebræ. The aorta then gains the middle line, and passing between the lowest dorsal vertebra and the crura of the diaphragm, enters the abdomen in the usual manner.

Besides the deviations from the natural form and position of the aorta now mentioned, the vessel also presents an appearance, not very uncommon in cases of aortic abnormality, of a dilated or bulging portion, which causes a marked projection towards the left side of the upper part of the descending aorta, and in front of the bodies of the third and fourth dorsal vertebræ; and this dilatation is situated so close to the back of the gullet and trachea as partly to embrace firmly these viscera.

The nature and position of such a dilatation of the aorta will be best understood from the sketch given in Fig. 3 of another example of right aortic arch presented by a preparation coming into my possession from the Jeffray collection. In this instance, however, the bulging part of the aorta marked *a'* does not project to so great an extent as in the first case. From what is afterwards stated it will be made apparent that this bulging part of the aorta represents an abnormal vestige of the left root of the descending aorta, or the posterior part of the natural left arch. A somewhat similar dilatation is occasionally observed even in the natural or left disposition of the aortic arch, and in such cases it marks the place of union of the cord of the ductus arteriosus with the back of the aortic arch. In a different class of abnormal

aortic vessels, to be again adverted to, viz., those in which, with either a right or left aortic arch, one of the subclavian arteries, which would in the natural state have been the first, is displaced so as to spring from the back part of the arch, and gains its usual place over the first rib by passing behind the trachea and gullet: in such cases the origin of the abnormal subclavian artery marks the situation of the dilatation now referred to.

In the case before us the principal arteries of the head and upper limbs take their origin from the arch of the aorta in the following manner:—The first of these vessels, corresponding to a left innominate or brachio-cephalic artery, springs from the anterior and left surface of the ascending portion of the arch, considerably nearer the heart than in the normal condition, and forms a trunk of the length of scarcely more than an inch, which lies obliquely across the trachea towards the left, and divides while still lying upon that tube into two vessels, the left common carotid and the left subclavian arteries. These vessels are longer than usual, in consequence of the shortness of the innominate trunk and the low places of its origin and division; but otherwise, their form and relations, allowing for inversion of the sides, do not differ very materially from those which naturally belong to the normal right carotid and subclavian arteries proceeding from a usual innominate trunk. The second vessel springing from the arch is the right common carotid artery. It rises from the forepart of the bent portion of the arch, about an inch and a half from the innominate artery, and proceeding upwards to the right of the trachea, subsequently takes the usual course of a right carotid artery. The third vessel, which forms the right subclavian artery, takes its departure from the summit of the arch previous to its turning down into the descending portion. It rises nearly vertically behind the inner part of the right clavicle, and, having gained its highest point, takes a sudden turn over the first rib behind the scalenus anticus muscle, to undergo beyond this place the usual distribution of the right subclavian artery. This artery, therefore, corresponds in its general relations on the right side to the usual left subclavian artery, and chiefly differs from it in the shortness of the first part of its trunk, which is caused in part by the greater than natural height of the summit of the arch of the aorta.

The trunk of the pulmonary artery and its primary right and left branches do not differ from the natural ones. From the root of the left pulmonary artery, as in ordinary cases, the impervious cord which forms the remains of the ductus arteriosus Botalli, proceeds backwards and upwards to the pointed extremity of the bulging part of the aorta (*a'*), with which it is completely united—a disposition which, if we except the greater length of the cord,

amounting in this case to an inch and a quarter, scarcely differs from what is usual.

One of the most interesting peculiarities of this specimen consists in the union of the bulging part of the aorta with the trunk of the left subclavian artery, at the distance of about three-quarters of an inch from the division of the innominate artery. This union is effected by means of a flat fibrous band, equally impervious with the cord of the ductus arteriosus, but considerably broader, and not more than half-an-inch in length. This band runs completely into the substance of the wall of the bulging part of the aorta, immediately above the cord of the ductus arteriosus. And thus it happens that the trachea and gullet are completely encircled or inclosed by arterial structures and their vestiges, viz., on the right by the aortic arch, behind by the bulging part or left aortic root, and in front and on the left side by the innominate trunk, the first part of the left subclavian artery, and the impervious band between it and the bulging part of the aorta. There can be no doubt, therefore, from the relations of the parts to each other, that the vessels and band last mentioned represent the usual left arch of the aorta.

With respect to the remaining bloodvessels little need be said to complete their description in this specimen, as they are all nearly natural. The superior vena cava is formed as usual by the union of the right and left brachio-cephalic veins, which differ in no important points from the normal condition. The vena azygos, which in the thorax occupies its usual place to the right of the descending aorta, is formed in the regular manner by the junction of the intercostal veins, and passes over the right lung to fall into the vena cava superior. The passage of the vena cava inferior through the diaphragm, and the place of its entrance into the right auricle, are natural. The vertebral, internal mammary, inferior thyroid, and other branches of the subclavian arteries, arise from the main vessel, and pass to their respective destinations without greater varieties than are frequently met with in ordinary specimens.

The course of the pneumogastric nerves in the vicinity of the arches, being modified by the peculiarities of this case, deserves special notice. On the right side, the nerve descending from the neck between the right carotid and subclavian arteries, passes over the upper and anterior part of the aortic arch, and from thence descends behind the right bronchus; but on arriving below the aortic arch, the nerve gives off its recurrent branch, which passes below the arch of the aorta to gain its place between the gullet and trachea, by which it rises to the larynx. This nerve, therefore, is bent or hooked round the aortic arch from the right side, much in the same way as it usually is on the left side, with this

difference, that in the case before us it has no relation to the cord of the ductus arteriosus.

On the left side the pneumogastric nerve descends in the upper part of the chest obliquely in front of the first part of the left subclavian artery. On arriving opposite the bulging portion of the aorta, it gives off its recurrent branch, and descends from this behind the root of the left lung to the gullet, &c. The left recurrent nerve turns backwards and inwards round the cord of the ductus arteriosus and the band which unites the left subclavian to the bulging part of the aorta. The left pneumogastric nerve in entering the chest also gives off its usual superficial cardiac branch, which may be seen in fig. 2 at * joining the cardiac ganglion along with one of the principal cardiac branches from the cervical part of the sympathetic nerve.

It is farther to be remarked that, in this case, the thoracic duct presents an unusual disposition in the upper part of its course. In the thorax this duct occupies its normal place between the vena azygos and the descending aorta. On arriving at the level of the fourth dorsal vertebra, it passes between the aorta and the vertebral column. After this, however, it does not cross to the left side, but rising into the lower part of the neck between the right carotid and subclavian arteries, it forms an arch in front of the vertebral artery, and at the level of the seventh cervical vertebra again descends, to end in the right brachio-cephalic vein, in the angle between the jugular and subclavian veins, having been previously joined by numerous lymphatic vessels from the neck and shoulder of the right side. The lymphatic vessels of the left side were not observed, but it was ascertained that there was no thoracic duct joining the left innominate vein.

With respect to the preparation which is represented in fig. 3 of the Plate, I have little to remark, as it came into my possession from the Jeffray collection, without record of the case or dissection. It is obviously another instance of right aortic arch, and as it belongs to the rarer kind of this malformation in which a left innominate artery exists, I think it proper to put it upon record. It presents also the peculiar dilatation of the aorta which marks the place of the left root, and with which doubtless the cord of the ductus arteriosus had united. But, unfortunately, no more of the specimen has been preserved than what is shown in the figure. At the same time the preparation is interesting as affording a clear illustration of the peculiar form of the aorta in such cases.

It may be proper, before concluding this paper, to offer some reflections on the nature of the malformation now described, and on the relation in which it stands to others of an allied kind. To describe it, then, with reference to the fœtal condition from which

it has taken its origin, it may be stated to consist chiefly in the following deviations from the natural embryological changes—viz., First, A fully persistent and grown condition of the fourth right aortic vascular arch; Second, The conversion of the greater anterior part of the fourth left arch into a left innominate trunk, from which a subclavian artery is derived, the back part of the arch being closed, but its vestige remaining as a strong fibrous band connected with the left aortic root; and Third, The existence of a dilatation of the aorta representing the left aortic root, to which there remain attached the band now mentioned as proceeding from the modified fourth arch, and the impervious cord of the ductus arteriosus connecting it with the left pulmonary or fifth arch. It differs from Hommel's and Malacarne's cases of double aortic arch encircling the trachea and œsophagus * in this respect, that in these cases the left as well as the right arches were completely patent and nearly of equal size, whereas in my case the left arch was, as now stated, modified so as to be converted into an innominate artery, and the origin of the great vessels took place nearly in the same manner, but in the inverse order from that of the usual left aorta, and the back part of the arch was completely closed.

The variety of aortic malformation now described appears to be extremely rare. I am aware, indeed, of only two other instances upon record in which, without transposition of the heart, the vessels have been observed to rise from a right aortic arch in the same manner. The first of these examples occurred in a new-born child, of which Mr. Quain has given a drawing in Plate VII., fig. 3, copied from a dissertation by Bernard, "De Arteriarum e corde prodeuntium aberrationibus," Berolini, 1818. Here the right aortic arch gives rise to a left innominate artery, with the subclavian branch of which, not far from its origin, the ductus arteriosus is joined. The second case is one published by Dubreuil in his work, "Sur les Anomalies des Artères," &c., Montpellier, 1847, Plate II., fig. 1, also presenting the same feature of a left innominate artery, proceeding as the first vessel from a right aortic arch, and without any other apparent deviation from the natural disposition of the parts; and in this instance the ductus arteriosus was observed to join the back part of the aorta.†

* As figured in Tiedemann, Tab. IV., figs. 6 and 7; and in Quain, Plate V., figs. 10 and 11.

† Other cases of the same kind have been referred to, but they all appear to be combined with some transposition of the heart. Such is the case with that of a child of about ten months old, described by Mr. Abernethy in the Philosophical Transactions for 1793, and of which Mr. Quain has given a drawing in Plate V., fig. 5, of his work. In this instance the right aorta, no doubt, gives off in succession the left innominate, the right carotid, and the right subclavian arteries; but the state of the ductus arteriosus is not represented, and it is

These two cases, although agreeing with the one I have described in having a left innominate as the first arterial trunk from the right aortic arch, seem to differ from each other in the mode of attachment of the ductus arteriosus behind, and they differ from my case in the absence of the vestige of the back part of the left fourth arch.

The preparation which is represented in fig. 3 of the Plate presents a third example of the same mode of origin of the great vessels; but unfortunately there is no record of the state of the ductus arteriosus or other parts.

There is, however, on record a greater number of cases of right aortic arch, combined with a disposition of the vessels rising from the arch, analogous to that which has been much more frequently observed in cases in which the aorta forms its arch normally to the left side. In these instances the first large vessel proceeding from the arch is a common carotid, while the subclavian artery, which, if the disposition had been natural, would have been connected with this carotid in an innominate trunk, is displaced so as to proceed from the back part of the aorta, and pass behind the trachea and gullet to gain its usual place over the first rib.

In the case of the aortic arch being a right one, the left carotid is the first vessel to spring from the arch; next comes the right carotid; and third, the right subclavian; and the left subclavian artery, rising, as it has been described by authors, fourth from the arch, but in reality from the left aortic root, passes, as above stated, behind the trachea and gullet upwards to its place on the left rib. Mr. Turner has described and figured an instance of this kind observed by himself, which clearly elucidates the nature of such cases.

I believe, indeed, that several cases of malposition of the great vessels, which have been described by authors, and which have appeared anomalous, or not referrible to any of the series of forms mentioned as susceptible of explanation on embryological principles, belong to the group now under consideration. Thus, as I suggested in my letter to Mr. Turner, printed in his paper already referred to,* the fifth and sixth figures of Table III. of Tiedemann's work; and the twelfth figure of Plate VI. and figs. 2 and 2*b* of Plate VII. of Quain's work, have all probably been exam-

obviously an example of lateral transposition or inversion of the heart. I cannot but suppose that when the true distinction between cases of inversion and mere substitution of a right for a left aortic arch comes to be more fully understood, we shall receive from anatomists an account of a greater number of such examples of malformation than have as yet been put upon record.

* British and Foreign Med. Chir. Rev. for July, 1862, p. 185. The reference given above to Quain's Plate VII., figs. 2 and 2*b*, was erroneously quoted in my letter to Mr. Turner as 1 and 1*b*.

ples of right aortic arches, though not recognized as such by those who described them.

Examples of the displacement of the right subclavian artery from the usual left aortic arch are numerous. Mr. Quain and Mr. Turner, who have described them well, consider the frequency of this malformation to amount to one in two hundred and fifty bodies observed in dissection; and the proportion has been estimated as still much higher, but probably far too high, by Hyrtl. In the superintendence of the dissection of about eight hundred bodies, with my attention alive to such observations, I have had five instances brought under my notice; but to establish a fair average of the proportion of such cases to the whole number of dissections, observations must be continued over a more extensive range.

In these dissections, however, it is deserving of being noticed, there has not occurred, so far as I am aware, a single instance of *right* aortic arch with displacement of the *left* subclavian artery to the back.

It is an interesting peculiarity of such cases as have now been referred to, which has been noted by myself and by a variety of observers, that the inferior laryngeal nerve, in a case of displaced right subclavian artery, with a left aortic arch, is not hooked down, as usual, by the arched portion of the subclavian artery, but passes directly towards its distribution in the trachea, gullet, larynx, heart, &c., behind the common carotid artery. Mr. Turner, referring to this fact, has given the correct embryological explanation of it, adopting, as he mentions, that which has been given by Mr. John Wood in a paper, published in 1859, in the Transactions of the Pathological Society, but which I have not had an opportunity of perusing.

This explanation consists in the supposition that the right arch, beyond the origin of the right carotid artery, or in that part which would normally have been continued into the right subclavian artery, had become atrophied, and had entirely disappeared; while the lower part of the right aortic root had remained patent, and had continued to grow in connection with the back part of the aorta, and being in communication with the origin of the right subclavian artery, carried the blood into that vessel, which had been detached from its natural supplying channel. The recurrent nerve was thus no longer held down by the fourth arch on the right side.

This is an explanation which I have long been in the habit of giving in my lectures; and I may state that, in the year 1853, having been applied to by Dr. John Struthers for my views on the subject in connection with an observation of the fact in question which he had made, I wrote to him substantially the

above explanation, and gave a diagram of the transitory condition of the parts, in illustration. Indeed, I think such an explanation must have been generally adopted by all those who were acquainted with embryology. I ought to state farther, however, that at the time referred to I still adhered to Von Baer's view of the origin of the innominate trunk from the third arch.

It is deserving of notice, farther, that in those cases of right aortic arch with displacement of the left subclavian to the back, in which the ductus arteriosus has joined the latter vessel, the recurrent laryngeal nerve is hooked round the cord of the ductus arteriosus.

It will have been seen, from the statements in the preceding paper, and from Mr. Turner's very lucid exposition of the subject, how much Rathke's view of the origin of the subclavian artery from the aortic root beyond the fourth arch, and farther down considerably on the right than on the left side, tends to clear up the whole of this very curious subject.

In conclusion, I may remark that, although the foregoing details may appear to some readers unnecessarily prolonged, I have thought it right to bring them forward in connection with this case, because it has appeared to me, more fully than any other single instance with which I am acquainted, to link together a considerable number of the allied malformations of the principal aortic arches, and to place, in a striking point of view, the relation subsisting between the non-symmetrical form of the arch itself, and of its principal branches in the adult, and the truly symmetrical and regular arterial framework of the fœtus.

On a future occasion I hope to be able to recur to this subject in connection with certain malformations of the descending aorta.

DESCRIPTION OF THE PLATE.

Figs. 1 and 2.—Representations of the right and left sides of the first preparation of right aortic arch, with some of the adjacent parts.

Fig. 3.—Sketch of the second preparation of right aortic arch.

In all the figures the several parts are indicated as follows:—

v, The right ventricle.

v', The left ventricle.

h, The right auricle, receiving above, the superior vena cava, and below, the inferior vena cava after it passes through the diaphragm.

h', The left auricle, into which are seen passing the left pulmonary veins.

A, The ascending stem of the aorta.

A' The descending thoracic aorta.

a, The right root, *a'*, the left root of the descending aorta; and in these preparations the bulging part which occupies the place of the latter.

p, The stem of the pulmonary artery; *p*, its right branch; *p'*, its left branch.

v i, Right innominate or brachio-cephalic vein, receiving at its extremity the thoracic duct, *t d*.

v i', Left brachio-cephalic vein.

i. The innominate or brachio-cephalic artery; in these cases dividing into the left subclavian and carotid arteries.

c, The right carotid artery, *c'*, the left carotid artery, placed one on each side of the trachea.

s, The right, *s'* the left subclavian arteries. These arteries are seen lying in their usual place over the first ribs, which are cut short in front of the attachment of the scalenus anticus muscle. On the right side a part of the scalenus muscle is represented as removed, to show the arch of the subclavian artery more fully. On both sides the subclavian arteries are seen to give rise to the vertebral, internal mammary and inferior thyroid arteries, and along with the last artery on the right side the transverse cervical artery.

d a, Ductus arteriosus, passing from the commencement of the left pulmonary artery to the bulging part of the aorta, *a'*. In fig. 2 will be seen the thick short band which unites the same part of the aorta to the left subclavian artery.

t d, The thoracic duct, seen passing upwards between the vena azygos and descending aorta, then disappearing for a space behind the aortic arch, and reappearing above in a loop which has been brought forward so as to be in part laid upon the right carotid artery; its subsequent descent from which place to join the right brachio-cephalic vein in the angle of union of the right jugular and subclavian veins is also represented.

p n, The right pneumogastric nerve, descending from above, between the right carotid and subclavian arteries, passing over the arch of the aorta till it is lost behind the root of the right lung, but previously giving off the recurrent laryngeal nerve, which is seen in fig. 1 turning in below the aortic arch close to the bulging portion.

p n' The left pneumogastric nerve, seen descending over the left subclavian artery till it reaches the level of the bulging part of the aorta, from whence it passes down behind the root of the left lung. When lying on the bulging part of the aorta it gives off the left recurrent nerve, which is seen turning in below the ductus arteriosus. The left pneumogastric nerve is also seen in fig. 2 to give off its cardiac branch, which unites with another descending from the sympathetic nerve; the part represented as cut short between the aorta and pulmonary artery, is the cardiac ganglion.

t, The trachea, and *o*, the œsophagus, seen to be inclosed between the right aortic arch and the parts which correspond with the left arch.

Figs. 1 and 2 also indicate the nerves of the axillary plexus above the subclavian arteries, and the chains of sympathetic nerves and ganglia, with the intercostal nerves and vessels cut short, in the upper part of the chest.